13.013
Dynamics Quiz 3

Closed book, three sheets of notes, both sides.

1. (25 %) I wish to isolate a current meter from the flow-induced vibration of the fiberglass pipe to which it is attached. The current meter is a torpedo shaped object with a propeller at the back end. It is available for inspection in class. The current meter is to be tethered to the tubing by some means as shown in figure (a). The tether wires presently on the current meter are very stiff and would cause the meter to shake so much that the measurements would be no good.

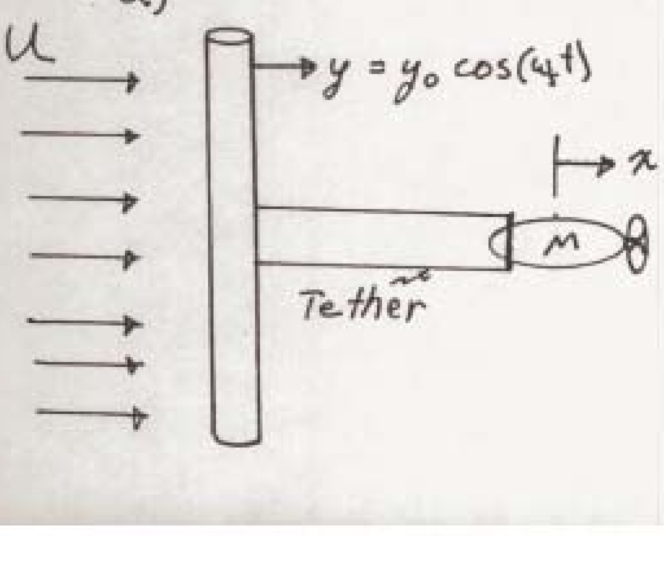
Relevant data:

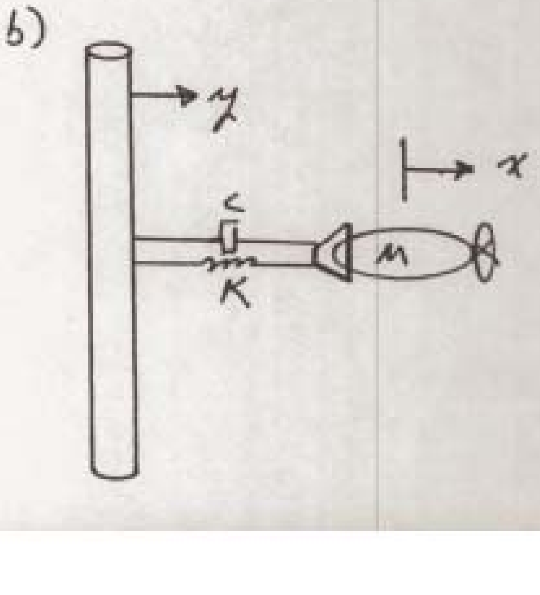
- At a speed through the water of 1.0 m/s the vibration frequency of the pipe in the plane of the tether and the current meter is $f_s = 10.0$ Hz.
- The vibration amplitude of the pipe in the direction of flow is $y_o = 0.025$m.
- The mass of the current meter including added mass is M = 0.4 kg.
- The mean drag force, F_{drag}, on the current meter is 1.0 N.

a. The vibration magnitude of the current meter, |x|, in the direction of the flow is not to exceed |x|=0.0025 m at the 1.0 m/s flow velocity. Design a simple vibration isolation system for the current meter by introducing a spring in the tether, as shown in figure (b). Assume for this preliminary calculation that the isolation system damping is zero. What is the ratio f_s/f_n that you have used to design your system. What is the ratio of |x|/|y| that your design will achieve.

b. At the frequency ratio found in part a, determine the expected response ratio, |x|/|y|, if the isolation system damping is 10% of critical.

c. As an important check on the design of the system, it is important to see if the static equilibrium stretch of the spring is reasonable. What is the static displacement of the fish on the spring, due to the mean drag force.





2. (25 %) This problem also pertains to the current meter tether system. Assume the vibration isolation system is in place. Further assume that the system has 10% of critical damping.

   a. If the motion of the pipe is 0.01 meters in magnitude with a frequency equal to the natural frequency of the system, what is your prediction of the magnitude of the motion of the current meter?

   b. Is there any practical limitation of this particular isolation system design that would make this prediction invalid?

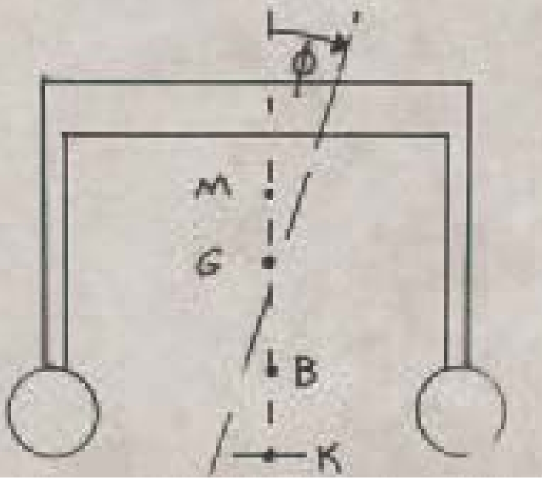
3. (25 %) On December 6th we ended class an hour early so that we could go hear and see the 13.018 presentation on the Swath vessel design. The roll behavior of the vessel depends on following data.

   - Total volume of fluid displaced by the SWATH model, when floating in static equilibrium is $0.108\ m^3$.
   - The waterline area of the vessel is $0.180\ m^2$.
   - The location of the center of gravity 'G', the center of buoyancy 'B' and the metacenter 'M' are shown on the diagram. Distances are measured up from the keel, K.
   - KG = 0.312 m, KB = 0.172 m, BM and GM you must compute from the data given.
   - $I_{xx,WP} = 0.0416\ m^4$. This is the moment of inertia of the water plane area with respect to the longitudinal centerline.
   - The mass moment of inertia about the roll axis of the vessel is given by $I_c = (M + M_{added})\kappa^2$, where $M_{added} = 0.1M$ and κ is the radius of gyration.

     $\kappa = b/2 = 0.457$ m, where b is the beam of the vessel.

   a. Estimate the natural frequency in roll. Use equations as far as possible before substituting in numbers, so that I can follow your work.

   b. If you really don't know how to do part 'a', for half credit you may compute instead an estimate of the heave natural frequency. You will not be given credit for both answers, but you will be given credit for whichever answer gives you the most points.



4. (25 %) At the exam there is a duck mobile, which flaps its wings at one frequency for small motions. It may be modelled as a single degree of freedom oscillator.

   a. Use the stopwatch provided and measure the natural frequency of the flapping motion. Write down your raw data, before making the final computation.

   b. Make an estimate of the damping ratio. A sketch of the time history that you observed and your estimate of the values used would be helpful in understanding what you have done. There is a measuring stick provided.

   c. y(t) describes the vertical motion of the duck body as shown in the diagram, as measured from the equilibrium position.

      If the duck body is given an initial condition displacement of y_o, write an expression describing the motion of the duck body, y(t), as a function of time. Assume small motions and that the system acts as a linear single DOF system with linear viscous damping. Use symbols for frequencies and damping ratios, not numbers.